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A sales tax is better at promoting healthy diets than the fat tax and the thin subsidy

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Abstract

Rising prevalence of obesity among adults and children is a major policy issue in many countries. Two widely discussed instruments to address obesity are a tax on unhealthy foods (fat tax) and a subsidy on healthy foods (thin subsidy). We compare these two policies to a sales tax on all food products, taking into account the different opportunity costs in terms of time for healthy and unhealthy meals. We show that the policy which reduces obesity under the most general conditions is the sales tax without the fat tax and the thin subsidy. Moreover, this policy is the only one which unambiguously stimulates healthy consumption.

Keywords: fat tax, thin subsidy, sales tax, obesity

JEL Code: D11;I12;I18;H31;H51;

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1 Introduction

The proportion of people classified as overweight or obese has been rising in many countries during the last several decades (OECD, 2014)¹. In the U.S. 35.3% of adults are obese. Similar patterns are observed in Mexico (32.4% prevalence of obesity), New Zealand (31.3%), Hungary (28.5%), Australia (28.3%) and other countries (OECD, 2014).

Obesity has negative consequences for both the individuals who suffer from it and society as a whole. It may cause insulin resistance and diabetes (Trayhurn and Beattie, 2001) and increase the risk of some forms of cancer (Calle and Kaaks, 2004), while morbid obesity raises by around 30% the risk of mortality (Flegal et al., 2013). Furthermore, the costs of obesity-related illnesses are usually not fully paid by the affected individuals. Almost 90% of the total medical care costs of obesity in the U.S. in 2005 were incurred by health insurance companies, Medicare and Medicaid (Cawley and Meyerhoefer, 2012).

Two popular policy approaches to internalize the costs of obesity are a tax on unhealthy foods (fat tax or soda tax)² and a subsidy on healthy food products (thin subsidy). In recent years, an increasing number of countries have implemented some form of taxation: since 2011 France taxes sugar-sweetened beverages (SSBs), Finland taxes sweets and non-alcoholic beverages and Hungary taxes food products with health risks, while Mexico taxes SSBs and energy-dense foods since 2014 (WHO, 2015).

However, critics have pointed that these policies may be ineffective or even counterproductive in reducing obesity. Several possible mechanisms can lead to this result: a negative impact of the policy instruments on the optimal time allocation to physical activities, an ambiguous substitution effect on the demand for junk-food (Yaniv et al., 2009) and substitution to untaxed unhealthy food alternatives after an introduction of the tax (Schroeter et al., 2008).

Moreover, the existing literature has mostly neglected the empirically supported higher opportunity cost in terms of time of healthy relative to unhealthy food (with the notable exception of Yaniv et al., 2009). Compared to away-from-home (AFH) food, home-cooked meals are associated with higher consumption of fruits and vegetables; higher intake of fiber, iron and calcium; lower intake of fat and cholesterol; lower calorie density (Lin and Frazao, 1997, 1999; Guthrie et al., 2002) and lower weight (Chou et al., 2004; French et al., 2000; Duffey et al.,

¹An adult is defined as overweight if his/her body mass index (BMI), defined as weight in kilograms divided by height in meters squared, is between 25 and 30, and as obese, if BMI exceeds 30. An individual is morbidly obese if $BMI \geq 35$. For a discussion of BMI and other definitions of obesity, see Cawley (2015).

²Due to the convention in the literature to call the tax on unhealthy food a ‘fat tax’, we will also refer to it as a fat tax throughout this paper. However, the analysis also applies to a tax on other types of unhealthy food.

2007). Furthermore, higher frequency of food preparation raises the consumption of fruits and vegetables and lowers the intake of fat, SSBs and fast-food (McLaughlin et al., 2003; Larson et al., 2006; Laska et al., 2012; Monsivais et al., 2014; Wolfson and Bleich, 2015b). The positive dietary impact of frequent cooking occurs irrespectively of the weight-loss intentions of individuals (Wolfson and Bleich, 2015a). Kolodinsky and Goldstein (2011) estimate that 10 additional minutes of cooking time lower BMI by 0.13 points. Zick et al. (2011) find that 10 minutes food preparation lower the BMI of women by 0.17 points and do not affect the BMI of men, who, however, are a small share of the meal preparers in their data.

This article is the first to propose a sales tax on all food products as an instrument that promotes healthy diets. We take into account the higher opportunity cost in terms of time of healthy consumption in a model akin to that of Yaniv et al. (2009). The individual chooses between consumption of healthy and unhealthy food and has a fixed out-of-work time constraint, which can be spent on physical activities, cooking healthy food and genuine leisure. Preparing unhealthy food is not time consuming. The individual may either take into account the negative health consequences of obesity or (partially) neglect them. We are able to show that the policy, which reduces obesity under the least restrictive conditions, is a positive sales tax in the absence of a fat tax and a thin subsidy. Additionally, the implementation of a sales tax is the only policy that results in an unambiguous rise in the consumption of healthy food.

This result emerges due to the negative income effect of the sales tax on leisure, which lowers the opportunity cost of cooking healthy meals. This effect always dominates the negative income effect on consumption and, thus, healthy food intake is a positive function of the sales tax. On the other hand, the negative income effect lowers junk-food consumption unambiguously. Contrary to the sales tax, a tax on unhealthy food and a thin subsidy impose an ambiguous substitution effect on leisure and, hence, an indeterminate effect on the price of time. If the individual is non-weight conscious, the substitution effect on leisure is negative and stimulates healthy diets, while for weight-conscious individuals it may be positive and raise the demand for junk-food.

This paper is related to two stands of literature. The first seeks to explain the observed trend in obesity and the second analyzes the implementation of a fat tax and a thin subsidy.

The literature on obesity has focused on several factors which may explain its rise in recent decades. Philipson and Posner (1999) and Lakdawalla et al. (2005) show that technological change that lowers the cost of food and raises the cost of physical activity may raise the optimal weight of individuals. Levy (2002) and Dragone (2009) show in a dynamic model that an

individual may be rationally overweight, even when the full impact of obesity on health is taken into account. [Yaniv \(2002\)](#) analyzes rational non-adherence to a prescribed low-fat diet.

The implementation of a fat tax or a thin subsidy has been numerously proposed (see e.g. [Cash et al., 2004](#); [Leicester and Windmeijer, 2004](#); [Kamerow, 2010](#); [Brownell and Frieden, 2009](#); [Brownell et al., 2009](#)). The optimal tax on unhealthy food has been shown to be positive in paternalistic models where individuals exhibit present-bias in their consumption choices ([O'Donoghue and Rabin, 2003, 2006](#); [Haavio and Kotakorpi, 2011](#); [Cremer et al., 2012](#)).

The closest to this paper is the article from [Yaniv et al. \(2009\)](#). They analyze the fat tax and thin subsidy under consideration of the time costs of home-food preparation. Neither policy instrument is unambiguously obesity-reducing, because they may either increase junk-food consumption or lower physical activity, such that the overall impact on obesity is unclear.

There is strong empirical evidence that a fat tax does not necessarily reduce weight, because of a possible switch to untaxed alternatives ([Chouinard et al., 2007](#); [Schroeter et al., 2008](#); [Fletcher et al., 2010b](#); [Zhen et al., 2014](#)). [Schroeter et al. \(2008\)](#) estimate that a tax on food away-from-home and a subsidy on fruit and vegetables may increase obesity. [Zhen et al. \(2014\)](#) show that a tax on SSBs can reduce their consumption at the cost of higher intake of fat and sodium. Furthermore, [Fletcher et al. \(2010a,b\)](#) find empirical support that such taxes have a significant effect on SSB consumption, but insignificant or very small effect on weight. [Jeffery et al. \(1994\)](#) and [French et al. \(1997\)](#) find a significant short-term impact of subsidizing fruits and salads at university and high school cafeteria, which vanishes after the removal of the subsidy. On the other hand, [Ni Mhurchu et al. \(2010\)](#) conducted a randomized experiment in which the price of healthier foods had 12.5% discount. Six months later, the purchase of these food products had risen by 11%.

Our contribution to the literature is in showing that there exists a tax which reduces obesity and promotes healthy consumption under more general conditions, namely a sales tax on all food items. Moreover, the sales tax is, contrary to the other instruments, non-distortionary and lowers weight at a smaller utility cost.

The rest of the paper is organized as follows. Section 2 develops the model and solves for the optimal consumption mix and time allocation of the representative individual. Section 3 determines the impacts of the fat tax, the thin subsidy and the sales tax on junk-food consumption, healthy consumption and obesity and compares them. In Section 4 we discuss the policy implications of our results and Section 5 concludes.

2 The Model

We consider a one-period model of obesity similar to the framework developed by [Yaniv et al. \(2009\)](#)³. The representative agent is overweight and may consume either healthy meals H or unhealthy meals (junk-food) F . The calorie intake per meal is denoted by δ and ε for junk and healthy food, respectively. Furthermore, we impose $\delta > \varepsilon$, i.e. junk-food has more calories per unit. The individual burns calories while at rest, which is due to the functioning of the body and is measured by the basal metabolic rate (BMR). The BMR is influenced by individual characteristics such as body weight and metabolism and is independent of physical activity ([Broeder et al., 1992](#); [Smith et al., 1997](#)). In addition, the individual may choose to devote time x to a physical activity, which results in calorie expenditure at rate $\mu > 0$ per instant of time. We define obesity S as the weight gain in the period and it is given by

$$S = \delta F + \varepsilon H - \mu x - BMR. \quad (1)$$

Furthermore, eating may be either hunger-induced or not. In the latter case, we assume that people consume snacks, which are energy-dense and part of the junk-food F . Denote hunger-induced meals and snacks by M and F^s , respectively, such that

$$M + F^s = H + F. \quad (2)$$

Hence, the difference between the total meals consumed $H + F$ and the amount of meals needed to satiate hunger M gives the demand for snacks. Suppose that snacks are only a fixed proportion of total junk-food consumption, i.e. $F^s = \rho F$, $\rho \in]0, 1[$. Substituting in Equation (2) and solving it for H , we get $H = M - F(1 - \rho)$. We insert this expression for healthy meals in Equation (1) and derive

$$S = (\delta - \varepsilon(1 - \rho))F + \varepsilon M - \mu x - BMR. \quad (3)$$

Suppose now that in the absence of unhealthy consumption and physical activity weight remains constant ($S = 0$). This requires $\varepsilon M = BMR$, i.e. the intake of calories when hunger is satiated only through healthy meals equals the calorie expenditure on basal metabolism. In this case we

³This article generalizes the model of [Yaniv et al. \(2009\)](#) who focus only on fully weight-conscious and non-weight conscious individuals, while we allow the representative consumer to be partially weight-conscious.

can express obesity as a function of junk-food consumption and physical activity only:

$$S = \theta F - \mu x, \quad (4)$$

where $\theta \equiv (\delta - \varepsilon(1 - \rho)) > 0$ represents the net effect of one unit of unhealthy meals on obesity.

2.1 The Representative Individual

Following Yaniv et al. (2009), we assume that the individual purchases junk-food meals at a restaurant⁴. Thus, their preparation does not require time. On the other hand, healthy meals are prepared at home and require healthy ingredients and time.

Denote the healthy ingredients and time spent cooking by G and k , respectively. The production of H is characterized by the following Leontief production function:

$$H(G, k) = \min\left(\frac{G}{\alpha}, \frac{k}{\beta}\right), \quad (5)$$

where $\alpha > 0$ and $\beta > 0$ determine the quantity of ingredients and time needed to prepare a healthy meal.

Furthermore, the junk-food meals F and the healthy ingredients G are produced under perfect competition and their net prices equal the constant marginal costs of production p_F and p_G , respectively. The individual's income is denoted by I and is exogenous. The consumer spends it only on purchases of G and F such that

$$p_F(1 + \tau_C + \tau_F)F + p_G(1 + \tau_C - \sigma)G = I, \quad (6)$$

where $\tau_C > 0$ denotes a sales tax, which applies to both goods, $\tau_F > 0$ is a fat tax levied on unhealthy food and $\sigma > 0$ is a thin subsidy on the healthy ingredients. In order to simplify the notation in the remaining analysis, we denote the gross prices as $\tilde{p}_F \equiv p_F(1 + \tau_C + \tau_F)$ and $\tilde{p}_G \equiv p_G(1 + \tau_C - \sigma)$.

The out-of-work time of the individual is constant and normalized to unity. She divides it among time devoted to physical activity x , time spent cooking k and genuine leisure ℓ . Thus, the time constraint is given by

$$x + k + \ell = 1. \quad (7)$$

⁴Alternatively, they could be purchased from the grocery store in the form of pre-prepared foods or snacks.

The individual derives utility from the total meal consumption C , which is defined as

$$C = F + \gamma H, \tag{8}$$

where $\gamma > 0$ is a taste parameter. Furthermore, genuine leisure ℓ is the only welfare-enhancing allocation of time, while time spent exercising x and cooking k are not associated with direct utility benefits. Thus, utility is given by

$$U = U(C, \ell), \tag{9}$$

where $U_i > 0, U_{ii} < 0, U_{ij} \geq 0, i, j = C, \ell, i \neq j$. The assumption $U_{C\ell} \geq 0$ implies that leisure and consumption are normal goods. Moreover, U is concave in both arguments, i.e. $U_{CC}U_{\ell\ell} - U_{C\ell}^2 > 0$.

We use the weight gain $S(F, x)$ as a proxy for the negative health consequences of obesity and define the net utility of the individual as $U(C, \ell) - S(F, x)$. However, she may not take these negative health effects fully into account. In this case, the individual is said to be (partially) non-weight conscious. Therefore, the consumer maximizes the following net utility function:

$$NetU = U(C, \ell) - bS(F, x). \tag{10}$$

The parameter $b \in [0, 1]$ denotes the extent to which the consumer takes into account the impact of obesity on health ($b = 1$ denotes a fully weight-conscious and $b = 0$ a non-weight conscious individual). Alternatively, we could interpret b as a form of present-bias (see e.g. [O'Donoghue and Rabin, 2003, 2006](#), for this interpretation), because gross utility $U(C, \ell)$ represents the immediate gratification from consumption while the consequences of obesity occur at a later time.

2.2 Optimal Consumption and Time Allocation

The consumer maximizes the utility function (10) with respect to consumption C , leisure ℓ and physical activity x . Denote the optimal parameter values using superscript $*$. The time constraint (7) together with ℓ^* and x^* determine the time spent cooking k^* and, thus, the optimal amount of healthy meals $H^* = k^*/\beta$. Next, C^* and H^* can be plugged in Equation (8) in order to derive the optimal junk-food consumption F^* .

Before we solve the utility maximization problem, we consolidate the budget and time

constraints. First, we replace F and G in Equation (6) by $F = C - \gamma H$ and $G = \alpha H$. Second, we use the time constraint to express H as $H = k/\beta = (1 - x - \ell)/\beta$. Thus, Equation (6) can be rewritten as

$$C + \frac{(\gamma\tilde{p}_F - \alpha\tilde{p}_G)}{\beta\tilde{p}_F}(x + \ell) = \frac{I}{\tilde{p}_F} + \frac{(\gamma\tilde{p}_F - \alpha\tilde{p}_G)}{\beta\tilde{p}_F}. \quad (11)$$

The integrated budget constraint (11) presents the expenditures in terms of total consumption, leisure and physical activity. The term in front of $(x + \ell)$ gives the relative price of time in terms of consumption C and represents its opportunity cost. If $(x + \ell)$ goes up, then the time available for cooking declines, which lowers the consumption of healthy meals H by a factor $1/\beta$. This effect saves payments on healthy ingredients amounting to $\alpha\tilde{p}_G/\beta$. However, the individual needs more junk-food in order to consume a given amount of C and, thus, additional payments equal to $\gamma\tilde{p}_F/\beta$ arise. Hence, the opportunity cost of time is $(\gamma\tilde{p}_F - \alpha\tilde{p}_G)/\beta$ and dividing it by \tilde{p}_F , we derive the relative price of time. We make the technical assumption $\gamma\tilde{p}_F > \alpha\tilde{p}_G$, which is necessary for the price of time to be positive.

The objective function (10) depends directly on C, ℓ, F and x . We simplify the utility maximization problem by expressing consumption C and leisure ℓ as functions of junk-food consumption and time devoted to physical activities. Solving Equation (6) for the purchases of healthy ingredients G and using $G = \alpha H$, we get

$$H = \frac{I - \tilde{p}_F F}{\alpha\tilde{p}_G}. \quad (12)$$

Using the production function for healthy meals (5), we can rewrite the time spent cooking as $k = \beta H$, which together with Equation (12) and the time constraint (7) gives

$$\ell = 1 - x - \beta \frac{I - \tilde{p}_F F}{\alpha\tilde{p}_G}. \quad (13)$$

Furthermore, we can substitute Equation (12) in the definition of C and use the resulting expression together with (13) to rewrite the objective function as

$$NetU = U \left(F + \gamma \frac{I - \tilde{p}_F F}{\alpha\tilde{p}_G}, 1 - x - \beta \frac{I - \tilde{p}_F F}{\alpha\tilde{p}_G} \right) - bS(F, x). \quad (14)$$

The new objective function depends only on F and x . The first-order conditions are given by

$$\frac{\partial NetU}{\partial F} = U_C \left(1 - \frac{\gamma\tilde{p}_F}{\alpha\tilde{p}_G} \right) + U_\ell \frac{\beta\tilde{p}_F}{\alpha\tilde{p}_G} - b\theta = 0, \quad (15)$$

$$\frac{\partial NetU}{\partial x} = -U_\ell + b\mu \leq 0, \quad x \geq 0, \quad \frac{\partial NetU}{\partial x} x = 0. \quad (16)$$

Equation (15) shows that junk-food consumption has three effects on net utility. First, an increase in F raises directly total consumption C and lowers it indirectly through its negative impact on the disposable income for expenditures on healthy ingredients. The first term in (15) captures this effect. Second, the reduction in healthy consumption leads to less time spent cooking, which improves welfare, due to the additional time available for leisure. Third, F raises obesity at the rate θ , which lowers utility, if the individual is weight-conscious ($b > 0$).

According to Equation (16), physical activity has two effects on welfare. It reduces the time for leisure and, hence, utility at the rate $-U_\ell < 0$. On the other hand, it improves welfare of a weight-conscious individual by burning μ calories.

Furthermore, the above equations show that the solution of the maximization problem consists of two cases: one with an interior solution ($F^* > 0, x^* > 0$) and one with a corner solution for physical activity ($F^* > 0, x^* = 0$). In the latter case, the optimality conditions can be rewritten as

$$\frac{U_\ell}{U_C} = \frac{(\gamma\tilde{p}_F - \alpha\tilde{p}_G)}{\beta\tilde{p}_F - b\theta\alpha\tilde{p}_G/U_\ell} \equiv \pi, \quad (15')$$

$$x^* = 0. \quad (16')$$

Equation (15') equates the marginal rate of substitution between consumption and leisure to the perceived relative price of leisure, which we denote by π . Note that the right-hand side of (15') differs from the price of leisure as defined in Equation (11) if the individual is weight-conscious, i.e. if $b > 0$. In this case the individual takes into account that the opportunity cost of spending more time in genuine leisure is augmented by the impact of F on obesity. A rise in ℓ lowers the time available for cooking, which means that more unhealthy meals are necessary in order to achieve a given level of total consumption. This raises not only the monetary costs of the consumer but also obesity.

If the optimal time devoted to physical activity is positive, then utility is maximized under the following conditions:⁵

$$U_C = b \frac{\theta\alpha\tilde{p}_G - \mu\beta\tilde{p}_F}{\alpha\tilde{p}_G - \gamma\tilde{p}_F}, \quad (15'')$$

$$U_\ell = b\mu. \quad (16'')$$

⁵This case can only emerge if the right-hand side of Equation (15'') is positive, i.e. if $\theta\alpha\tilde{p}_G < \mu\beta\tilde{p}_F$.

In the next section we consider how the three policy instruments affect the optimal consumption, physical activity and obesity of the representative individual.

3 Taxes and Obesity

This article aims at finding the tax or subsidy that is best suited to reduce obesity without analyzing whether or when such an intervention is desirable. We will be able to clearly identify the general sales tax as the instrument which lowers obesity under the least restrictive conditions. The introduction of either a fat tax or a thin subsidy not only has a more ambiguous impact on obesity, but also restricts the sales tax's effectiveness and renders its impact undetermined. Since there are three policy instruments and two possible cases, we consider the implications of all instruments in each situation separately.

3.1 A Physically Inactive Individual

Equations (15') and (16') describe the behavior of the physically inactive individual. A change in each policy instrument exerts income and substitution effects on total consumption C^* and leisure ℓ^* . The combined effect on consumption and leisure determines how the quantities of healthy and unhealthy meals change and, ultimately, the impact of the policy parameter on obesity.

The substitution effect is determined by the change in the perceived relative price of leisure π . Taking the partial derivatives of π with respect to τ_F, τ_C and σ and simplifying, we get⁶

$$\pi_{\tau_F} \propto (\beta U_\ell - \gamma b\theta) = (U_C - b\theta) \frac{\gamma \tilde{p}_F - \alpha \tilde{p}_G}{\tilde{p}_F} \geq 0 \quad \Leftrightarrow \quad (U_C - b\theta) \geq 0, \quad (17a)$$

$$\pi_\sigma \propto (\beta U_\ell - \gamma b\theta) = (U_C - b\theta) \frac{\gamma \tilde{p}_F - \alpha \tilde{p}_G}{\tilde{p}_F} \geq 0 \quad \Leftrightarrow \quad (U_C - b\theta) \geq 0, \quad (17b)$$

$$\pi_{\tau_C} \propto -(\tau_F + \sigma)(\beta U_\ell - \gamma b\theta) = 0 \quad \Leftrightarrow \quad \tau_F = \sigma = 0. \quad (17c)$$

The above Equations show that the fat tax and the thin subsidy have a positive effect on the perceived price of leisure if $U_C - b\theta > 0$ and vice versa. Thus, these instruments impose an unambiguously negative substitution effect on leisure, if the individual is non-weight conscious. However, this effect is ambiguous when the individual takes into account the costs of obesity. On the other hand, the sales tax does not impact the price of leisure when $\tau_F = \sigma = 0$.

⁶In deriving the second equalities in Equations (17a) and (17b), we used the first-order condition (15').

Consider now the effect of the fat tax on F^* and H^* . Equation (15') determines junk-food consumption, while H^* follows from Equation (12). Totally differentiating these equations with respect to F, H and the policy parameter τ_F , we derive the following impact of the fat tax on the individual's behavior:

$$\begin{aligned} \frac{\partial F^*}{\partial \tau_F} &= \frac{p_F F}{\alpha \tilde{p}_G D_1} \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G} \right) (\gamma U_{CC} - \beta U_{C\ell}) + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} (\gamma U_{\ell C} - \beta U_{\ell\ell}) \right] \\ &\quad + \frac{p_F (U_C - b\theta)}{\tilde{p}_F D_1} < 0, \quad \text{if } U_C > b\theta, \end{aligned} \quad (18a)$$

$$\frac{\partial H^*}{\partial \tau_F} = - \frac{p_F F \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G} \right) U_{CC} + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} U_{C\ell} \right] + p_F (U_C - b\theta)}{\alpha \tilde{p}_G D_1} > 0, \quad \text{if } U_C > b\theta, \quad (18b)$$

where D_1 is given by

$$D_1 \equiv \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G} \right)^2 U_{CC} + 2 \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G} \right) \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} U_{C\ell} + \left(\frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} \right)^2 U_{\ell\ell} < 0.$$

First, we interpret Equation (18a). A fat tax has two effects on unhealthy consumption. The term in brackets in Equation (18a) represents the income effect of the tax and is unambiguously negative. The second term describes the substitution effect and is also negative if and only if $U_C - b\theta > 0$. This condition is fulfilled if the individual is non-weight conscious, i.e. if $b = 0$. Thus, for non-weight conscious individuals F^* is unambiguously declining in τ_F . However, if $U_C - b\theta < 0$, the perceived relative price of leisure is declining in the fat tax. The lower price stimulates genuine leisure, which lowers the time available for cooking and, thus, raises junk-food consumption. Hence, the substitution effect on F^* is positive. Furthermore, the impact on healthy consumption H^* is positive when $U_C - b\theta > 0$ because of the negative income and substitution effects on leisure. The change in H^* is undetermined when the substitution effect reverses its sign.

Lastly, the changes in obesity and junk-food consumption are of the same sign due to $x^* = 0$. Thus, the impact of τ_F on obesity is negative if $U_C - b\theta > 0$ and indeterminate otherwise.

Next we turn to the thin subsidy. Repeating the analogous calculations, we derive the following comparative statics results:

$$\begin{aligned} \frac{\partial F^*}{\partial \sigma} &= \frac{p_G G}{\alpha \tilde{p}_G D_1} \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G} \right) (\beta U_{C\ell} - \gamma U_{CC}) + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} (\beta U_{\ell\ell} - \gamma U_{\ell C}) \right] \\ &\quad + \frac{p_G (U_C - b\theta)}{\tilde{p}_G D_1} > 0, \quad \text{if } U_C < b\theta, \end{aligned} \quad (19a)$$

$$\frac{\partial H^*}{\partial \sigma} = \frac{p_G G \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) U_{CC} + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} U_{Cl} \right] - \frac{\tilde{p}_F p_G}{\tilde{p}_G} (U_C - b\theta)}{\alpha \tilde{p}_G D_1} < 0, \quad \text{if } U_C < b\theta. \quad (19b)$$

A thin subsidy also has an ambiguous effect on consumption and obesity. Equation (19a) shows that it has a positive income effect on junk-food consumption (represented by the first term in (19a)) and a positive substitution effect if $U_C - b\theta < 0$. In this case unhealthy consumption and obesity increase. On the other hand, if $U_C - b\theta > 0$, then the effect is ambiguous. Furthermore, H^* is a declining function of the thin subsidy if $U_C - b\theta < 0$ because in this case both the income and substitution effects on leisure are positive, i.e. the opportunity costs of food preparation increase.

Consider now the sales tax. We derive the following comparative statics results of an increase in τ_C :

$$\begin{aligned} \frac{\partial F^*}{\partial \tau_C} = & \frac{p_G I \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) (\gamma U_{CC} - \beta U_{Cl}) + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} (\gamma U_{lC} - \beta U_{ll}) \right]}{\alpha \tilde{p}_G^2 D_1} - \frac{p_F p_G (\tau_F + \sigma)}{\alpha \tilde{p}_G^2 D} \left[(U_C - b\theta) \frac{\alpha \tilde{p}_G}{\tilde{p}_F} \right. \\ & \left. + F \left(\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) (\gamma U_{CC} - \beta U_{Cl}) + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} (\gamma U_{lC} - \beta U_{ll}) \right) \right] < 0, \quad \text{if } \tau_F = \sigma = 0, \end{aligned} \quad (20a)$$

$$\begin{aligned} \frac{\partial H^*}{\partial \tau_C} = & -\frac{p_G I}{\alpha \tilde{p}_G^2 D_1} \left[\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) U_{CC} + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} U_{Cl} \right] + \frac{p_F p_G (\tau_F + \sigma)}{\alpha \tilde{p}_G^2 D_1} \left[(U_C - b\theta) \right. \\ & \left. + F \left(\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) U_{CC} + \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} U_{Cl} \right) \right] > 0, \quad \text{if } \tau_F = \sigma = 0. \end{aligned} \quad (20b)$$

According to Equation (20a), the sales tax has a negative income effect on F^* (represented by the first term) and a substitution effect which vanishes when $\tau_F = \sigma = 0$. Thus, in the absence of a fat tax and a thin subsidy, the sales tax lowers junk-food consumption and obesity. Furthermore, the impact on healthy consumption is unambiguously positive under the same condition. The intuition is the following: if $\tau_F = \sigma = 0$, then the relative price of time does not change, while the income effects on C and ℓ are negative. The reduced leisure frees up time for cooking. Hence, it leads to an unambiguous increase in healthy consumption. On the other hand, F declines by more than the reduction in C .

We summarize these results in the following Proposition:

Proposition 1 (i) *The fat tax lowers junk-food consumption and obesity and stimulates healthy consumption of a physically inactive individual, if $U_C - b\theta > 0$. Otherwise, its effects are indeterminate.*

(ii) The thin subsidy raises junk-food consumption and obesity and lowers healthy consumption of a physically inactive individual, if $U_C - b\theta < 0$. Otherwise, its effects are indeterminate.

(iii) The sales tax unambiguously lowers junk-food consumption and obesity and stimulates healthy consumption of a physically inactive individual, when there is no fat tax or thin subsidy.

Parts (i) and (ii) of Proposition 1 generalize the results of Yaniv et al. (2009), who consider only the special cases $b = 0$ and $b = 1$. However, the main result is in part (iii) of this Proposition. A sales tax is the only instrument which can unambiguously reduce obesity and stimulate healthy consumption of a physically inactive individual.

3.2 The Physically Active Individual

If the consumer is physically active, then Equations (15'') and (16'') together determine F^* and x^* . In order to find the effects of the policy parameters on obesity, we need to derive their impacts on both junk-food consumption and physical activity. First, we totally differentiate the two first-order conditions (15'') and (16'') with respect to F, x and the fat tax τ_F , which gives

$$\frac{\partial F^*}{\partial \tau_F} = \frac{p_F(\theta\gamma - \mu\beta)U_{\ell\ell}}{\alpha\tilde{p}_G \left(1 - \frac{\gamma\tilde{p}_F}{\alpha\tilde{p}_G}\right)^2 D_2} + \frac{\gamma p_F F}{\alpha\tilde{p}_G - \gamma\tilde{p}_F} < 0, \quad \text{if } \mu\beta \geq \theta\gamma, \quad (21a)$$

$$\frac{\partial x^*}{\partial \tau_F} = \frac{p_F(\theta\gamma - \mu\beta) \left[U_{C\ell} \left(1 - \frac{\gamma\tilde{p}_F}{\alpha\tilde{p}_G}\right) + U_{\ell\ell} \frac{\beta\tilde{p}_F}{\alpha\tilde{p}_G} \right]}{\alpha\tilde{p}_G \left(1 - \frac{\gamma\tilde{p}_F}{\alpha\tilde{p}_G}\right)^2 D_2} + \frac{\beta p_F F}{\alpha\tilde{p}_G - \gamma\tilde{p}_F} < 0, \quad \text{if } \mu\beta \geq \theta\gamma, \quad (21b)$$

where D_2 is given by

$$D_2 \equiv \left(1 - \frac{\gamma\tilde{p}_F}{\alpha\tilde{p}_G}\right) (U_{CC}U_{\ell\ell} - U_{C\ell}^2) < 0.$$

The interpretation of Equation (21a) is similar to the previous case. The second term is negative and represents the negative income effect of a rise in τ_F . The first term represents the substitution effect and has the sign of $\theta\gamma - \mu\beta$. The reason is that, as in the previous case, the change in the relative price of leisure is ambiguous. In order to see this, divide (16'') by (15''). The resulting expression contains the marginal rate of substitution between leisure and consumption U_{ℓ}/U_C on the left-hand side and the perceived relative price of leisure on the right-hand side. This relative price is increasing (decreasing) in τ_F if $\mu\beta > (<)\theta\gamma$. Thus, if the first inequality is fulfilled, the substitution effect on leisure is negative. This effect augments the time available

for cooking and, hence, lowers the amount of junk-food meals necessary for a given C . The interpretation of the effect on x^* is analogous. The second term in (21b) gives the negative income effect on x^* , while the first term represents the substitution effect. It again stems from the change in the relative price of leisure, i.e. if $\mu\beta > \theta\gamma$, there is a negative substitution effect on ℓ^* , which leads to a decline in physical activities.

We use Equation (12) in order to derive the change in healthy consumption H^* :

$$\frac{\partial H^*}{\partial \tau_F} = -\frac{p_F F}{\alpha \tilde{p}_G} - \frac{\tilde{p}_F}{\alpha \tilde{p}_G} \frac{\partial F^*}{\partial \tau_F} \underset{\leq}{\geq} 0. \quad (22)$$

The impact on H^* is ambiguous, because a fat tax has a direct negative effect on it through raising junk-food expenditures for a given F^* and an ambiguous impact through the change in the demand for unhealthy food.

On the other hand, the change in obesity is driven by the effects on F^* and x^* . Differentiating Equation (4) with respect to τ_F , we derive⁷

$$\frac{\partial S}{\partial \tau_F} = \frac{p_F(\theta\gamma - \mu\beta)}{(\alpha \tilde{p}_G - \gamma \tilde{p}_F)} [F + (U_{\ell\ell}U_C - U_\ell U_{C\ell})/D_2] \underset{\geq}{\leq} 0 \quad \Leftrightarrow \quad \mu\beta \underset{\geq}{\leq} \theta\gamma. \quad (23)$$

Obesity declines if and only if $\mu\beta < \theta\gamma$. In order to interpret this result, it is helpful to derive the changes in C^* and ℓ^* . Equations (8), (21a) and (22) determine the effect on total consumption, while (16'') gives the change in leisure:

$$\begin{aligned} \frac{\partial C^*}{\partial \tau_F} &= \frac{p_F(\theta\gamma - \mu\beta)U_{\ell\ell}}{(\alpha \tilde{p}_G - \gamma \tilde{p}_F)D_2} \underset{\geq}{\leq} 0 \quad \Leftrightarrow \quad \mu\beta \underset{\geq}{\leq} \theta\gamma; \\ \frac{\partial \ell^*}{\partial \tau_F} &= -\frac{U_{\ell C}}{U_{\ell\ell}} \frac{\partial C^*}{\partial \tau_F} \underset{\geq}{\leq} 0 \quad \Leftrightarrow \quad \frac{\partial C^*}{\partial \tau_F} \underset{\geq}{\leq} 0. \end{aligned}$$

Thus, consumption and leisure undergo the same qualitative change as obesity. Now we can explain Equation (23). Suppose $\mu\beta > \theta\gamma$ such that obesity increases. In this case the fat tax raises C^* and ℓ^* . However, junk-food consumption declines according to Equation (21a). Hence, H^* must increase by at least $-1/\gamma dF^*$, meaning that cooking time rises by more than $-\beta/\gamma dF^*$. Since ℓ^* also goes up, the time for physical activity must fall by at least $-\beta/\gamma dF^*$ and, thus, raise obesity at a factor more than $-\mu\beta/\gamma dF^*$. However, obesity falls due to the lower junk-food consumption at a rate θdF^* , meaning that the overall impact on obesity is at least $(\theta - \mu\beta/\gamma)dF^* > 0$.

Next, we derive the implications of a thin subsidy for junk-food consumption and physical

⁷In simplifying the right-hand side of Equation (23), we used Equations (15'') and (16'').

activity. The comparative statics gives the following results:

$$\frac{\partial F^*}{\partial \sigma} = \frac{\tilde{p}_F p_G (\theta\gamma - \mu\beta) U_{\ell\ell}}{\alpha \tilde{p}_G^2 \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right)^2 D_2} - \frac{\gamma p_G G}{\alpha \tilde{p}_G - \gamma \tilde{p}_F} > 0, \quad \text{if } \theta\gamma \geq \mu\beta, \quad (24a)$$

$$\frac{\partial x^*}{\partial \sigma} = \frac{\tilde{p}_F p_G (\theta\gamma - \mu\beta) \left[U_{C\ell} \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) + U_{\ell\ell} \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} \right]}{\alpha \tilde{p}_G^2 \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right)^2 D_2} - \frac{\beta p_G G}{\alpha \tilde{p}_G - \gamma \tilde{p}_F} > 0, \quad \text{if } \theta\gamma \geq \mu\beta. \quad (24b)$$

These results are similar to the case of an inactive individual. The thin subsidy imposes a positive income effect on F and x and if the substitution effect is also positive (i.e. if $\theta\gamma > \mu\beta$), then unhealthy consumption and physical activity are positive functions of σ . Moreover, the change in H^* is again ambiguous and given by

$$\frac{\partial H^*}{\partial \sigma} = \frac{p_G G}{\alpha \tilde{p}_G} - \frac{\tilde{p}_F}{\alpha \tilde{p}_G} \frac{\partial F^*}{\partial \sigma} \stackrel{?}{\leq} 0. \quad (25)$$

The thin subsidy has a positive income effect on healthy consumption and a sufficient condition for a positive overall effect is $dF^* < 0$.

Both the changes in junk-food consumption and physical activity affect obesity, which reacts to a higher subsidy in the following way:

$$\frac{\partial S}{\partial \sigma} = \frac{p_G (\theta\gamma - \mu\beta)}{(\alpha \tilde{p}_G - \gamma \tilde{p}_F)} \left[-G + \frac{(U_{\ell\ell} U_C - U_\ell U_{C\ell}) \tilde{p}_F}{\tilde{p}_G D_2} \right] \stackrel{?}{\geq} 0. \quad (26)$$

In this case it is not sufficient to determine the sign of $\mu\beta - \theta\gamma$ in order to derive the change in obesity. It declines if (i) $\theta\gamma > \mu\beta$ (as in the case of a fat tax) and (ii) G^* is small enough such that the term in brackets in Equation (26) is positive. Thus, the thin subsidy's impact on obesity has the correct sign under less generous conditions than the fat tax.

Lastly, we consider the sales tax. It affects junk-food consumption and physical activity according to:

$$\frac{\partial F^*}{\partial \tau_C} = \frac{\gamma p_G I / \tilde{p}_G}{(\alpha \tilde{p}_G - \gamma \tilde{p}_F)} - \frac{p_F p_G (\tau_F + \sigma)}{\alpha \tilde{p}_G^2 D_2} \left[\gamma F (U_{CC} U_{\ell\ell} - U_{C\ell}^2) + \frac{(\theta\gamma - \mu\beta) U_{\ell\ell}}{\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right)^2} \right] < 0, \quad \text{if } \tau_F = \sigma = 0, \quad (27a)$$

$$\frac{\partial x^*}{\partial \tau_C} = \frac{-p_F p_G (\tau_F + \sigma)}{\alpha \tilde{p}_G^2 D_2} \left[\beta F (U_{CC} U_{\ell\ell} - U_{C\ell}^2) + \frac{(\theta\gamma - \mu\beta)}{\left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right)^2} \left[U_{C\ell} \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right) + U_{\ell\ell} \frac{\beta \tilde{p}_F}{\alpha \tilde{p}_G} \right] \right]$$

$$+ \frac{\beta p_G I / \tilde{p}_G}{\alpha \tilde{p}_G - \gamma \tilde{p}_F} < 0, \quad \text{if } \tau_F = \sigma = 0. \quad (27b)$$

The above results show that a sales tax unambiguously lowers both junk-food consumption and physical activity, if there is no fat tax or thin subsidy, because then the sales tax is non-distortionary. Furthermore, it unambiguously raises consumption of healthy meals in this case:

$$\begin{aligned} \frac{\partial H^*}{\partial \tau_C} &= \frac{p_F p_G (\tau_F + \sigma)}{\alpha \tilde{p}_G^2} \left[F + \tilde{p}_F \left(\frac{\gamma F}{(\alpha \tilde{p}_G - \gamma \tilde{p}_F)} + \frac{(\theta \gamma - \mu \beta) U_{\ell \ell}}{\alpha \tilde{p}_G \left(1 - \frac{\gamma \tilde{p}_F}{\alpha \tilde{p}_G}\right)^2 D_2} \right) \right] \\ &\quad - \frac{p_G I / \tilde{p}_G}{\alpha \tilde{p}_G - \gamma \tilde{p}_F} > 0, \quad \text{if } \tau_F = \sigma = 0. \end{aligned} \quad (28)$$

Hence, the sales tax is the only policy instrument which unambiguously exerts a positive effect on the healthy consumption of a physically active individual (provided $\tau_F = \sigma = 0$).

In order to determine the effect of τ_C on obesity, we use Equations (4), (27a), (27b) and derive the following result:

$$\begin{aligned} \frac{\partial S}{\partial \tau_C} &= \frac{p_F p_G (\tau_F + \sigma) (\mu \beta - \theta \gamma)}{\tilde{p}_G (\alpha \tilde{p}_G - \gamma \tilde{p}_F)} \left[F + \frac{(U_C U_{\ell \ell} - U_\ell U_{C \ell})}{D_2} \right] \\ &\quad - \frac{p_G I (\mu \beta - \theta \gamma) / \tilde{p}_G}{\alpha \tilde{p}_G - \gamma \tilde{p}_F} \leq 0, \quad \text{if } \mu \beta \geq \theta \gamma, \quad \tau_F = \sigma = 0. \end{aligned} \quad (29)$$

According to Equation (29), in the absence of a fat tax and a thin subsidy the sales tax has an impact on obesity, which is qualitatively identical to the effect of τ_F and lowers obesity under less restrictive conditions than σ . We summarize these results in the following Proposition:

Proposition 2 (i) *The fat tax and the thin subsidy have ambiguous impacts on junk-food consumption, exercise and healthy consumption of a physically active individual. The sales tax unambiguously lowers junk-food consumption and physical activity and stimulates healthy consumption of a physically active individual, when there is no fat tax or thin subsidy.*

(ii) *Obesity of a physically active individual is reduced (increased) by the fat tax and the sales tax in the absence of a fat tax or a thin subsidy, if $\theta \gamma > (<) \mu \beta$. The sign of $\theta \gamma - \mu \beta$ does not suffice to determine the impact of a thin subsidy on obesity.*

4 Discussion

Propositions 1 and 2 have shown that a thin subsidy does not have an unambiguous effect on junk-food consumption, healthy consumption, physical activity and obesity in both scenarios.

The same result holds true for a fat tax even though it achieves the desired results under less restrictive assumptions than the thin subsidy. Thus, the fat tax is a better instrument than the thin subsidy.

The sales tax is the only policy instrument (when implemented alone) that lowers junk-food consumption and stimulates healthy consumption in all cases. Furthermore, it is the only instrument that reduces unambiguously obesity in the first case and has the same qualitative impact on weight as the fat tax in the second situation. Thus, the sales tax can achieve the social planner's aims of lower obesity and more healthy consumption under the most general conditions. This result emerges because a sales tax lowers the opportunity cost in terms of time of cooking and due to the healthiness of food prepared at home compared to away-from-home and pre-prepared meals.

Existing empirical studies shed light on how important the time constraint for the optimal time allocation to food preparation is. [Zick et al. \(2011\)](#) find the opportunity cost of time for men and women to be \$21/hr and \$16.84/hr, respectively. Thus, the time costs of meals that require long preparation may exceed their monetary costs. [Larson et al. \(2006\)](#) find that the most common barrier to food preparation is lack of time. Therefore, policy instruments that lower the opportunity cost of cooking (such as the sales tax) seem to be effective in promoting healthy diets.

Moreover, τ_C is non-distortionary and, hence, achieves the goal of healthier diets at a lower utility cost. Additionally, the sales tax has advantages, which were not considered in the formal model. While a fat tax can be avoided, either by switching to similar goods that are untaxed ([Fletcher et al., 2010b](#); [Zhen et al., 2014](#)) or by cross-border shopping ([Tosun and Skidmore, 2007](#)), a sales tax can only be avoided by cross-border shopping. Furthermore, the sales tax is associated with the least administrative costs for the government, as it is levied on all goods and does not require information on which goods (ingredients) are unhealthy or healthy. Lastly, it also imposes less compliance and concealment costs on firms, as they do not have to incur costs of redesigning their products for tax purposes.

5 Conclusions

This article has compared three different policy instruments, which can be used to address the problem of rising obesity levels: a fat tax, a thin subsidy and a sales tax on all food items. Even though the health economics literature focuses only on the first two, the policy which reduces

obesity and stimulates healthy consumption under the most general conditions in this model is a sales tax in the absence of the fat tax and the thin subsidy.

This result emerges because the fat tax and the thin subsidy impose ambiguous substitution effects on consumption and leisure. On the other hand, a sales tax is non-distortionary, i.e. it does not change the relative price of time. However, it exerts a negative income effect on leisure. Hence, it lowers the opportunity costs of spending time cooking, which stimulates individuals to prepare their meals and, therefore, consume more healthy food.

While the health benefits of home-prepared food are well-established in the empirical literature, there is no analysis of the impact of a sales tax on the healthiness of consumers' diets. Therefore, future empirical research should quantify these effects. Moreover, taxing all food products may be regressive, as poor households spend a larger proportion of their income on food relative to rich households. As a result, an important agenda for future research is to analyze how the tax receipts should be spent, such that the tax becomes less regressive. Lastly, this paper has contributed to the literature by emphasizing the time costs of healthy consumption and showing their importance for the optimal design of the policies that address obesity. Future research may focus on finding additional ways of lowering the opportunity cost of home food preparation.

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